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UNITED STATES BUREAU OF MINES
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INFORMATION CIRCULAR

USE OF AIRPLANES IN MINING AND PETROLEUM OPERATIONS

(ABSTRACT)

FROM AN UNPUBLISHED BULLETIN MANUSCRIPT

BY

HUGH M. WOLFLIN

(ABSTRACTED BY CHARLES WILL WRIGHT)

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[1] The Bureau of Mines will welcome reprinting of this paper, provided the following footnote acknowledgment is used: "Reprinted from U. S. Bureau of Mines Information Circular 6767."

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INTRODUCTION

This Information Circular is an abstract of a manuscript which was completed in June 1933, by Mr. Hugh M. Wolflin, formerly of the U. S. Bureau of Mines. This abstract has been prepared by Charles Will Wright for presentation at the February meeting of the American Institute of Mining and Metallurgical Engineers in New York. It has been necessary to omit many of the details and most of the cost data and tables, as well as the illustrations in the original manuscript. As the use of airplanes in mining developments is making such progress and as a publication on this subject to be of greatest value should include the most recent information, it is unfortunate that, due to a lack of printing funds, it has not been possible to publish this manuscript.

The purposes of Mr. Wolflin's paper are:

(1) To describe briefly what has been accomplished in some outstanding examples by the use of aircraft in the mining and petroleum industries,

(2) To record costs,

(3) To present available information and suggestions to assist in solving future air-transportation problems in the industries under consideration.

The manuscript is divided into seven chapters:

I. Prospecting and Exploration
II. Aerial Mapping
III. Air Transportation of Freight
IV. Individual Air Transportation
V. Landing Fields
VI. Dependability of Airplanes
VII. General Summary

It is well illustrated by diagrams and photographs and includes a bibliography of published articles on aviation from which part of the information in the manuscript was taken. Much of the data, however, was derived from correspondence with engineers and managers of air-transportation companies and others who contributed generously such information as they had available.

In the introduction Mr. Wolflin mentions the various means of transport used in isolated regions throughout the world; trains of native packers in Africa, dog teams in Alaska, canoes in Canada, and pack horses in the Rockies. He tells how airplanes were used at first for carrying prospecting parties, engineers and geologists to investigate new districts, then for mapping the topography and geology in these outlying areas, and describes the development of the big cargo plane for transporting heavy loads to otherwise almost inaccessible regions.

PROSPECTING, EXPLORATION AND SURVEYING BY AIRPLANE

In northern Canada and Alaska, airplanes have been used for prospecting and exploration, perhaps to a greater extent than elsewhere in the World, although several extensive surveys and exploration trips have been made with them in central Australia. The substitution of airplanes for more primitive methods of transportation in the North has been considerably advanced by the development of satisfactory landing gear; skis in winter and floats in summer. Much of the northern terrain has many lakes and rivers which serve as satisfactory landing places for pontoon-equipped aircraft during the summer. Good landing places are even more numerous for ski-equipped craft during the winter. As a rule there is not more than a month or two during the spring break-up and the autumn freeze when the use of aircraft is impracticable in these areas.

The satisfactory development of air-cooled engines for airplanes has been an important factor in increasing air transportation, particularly in areas where extremely low temperatures may be encountered. With the rapid increase in dependability and horsepower developed per unit of engine weight, the cruising range and pay load of aircraft have increased, also the efficiency and safety of air transportation in remote areas.

In general, it is conceded that the use of airplanes has increased both the safety and efficiency of prospecting and exploration in areas remote from centers of population.

A number of actual examples of aerial prospecting and exploring operations are summarized here for the information of organizations considering the examination of areas remote from transportation. While the details, particularly the cost data, are fragmentary, all the readily available information has been included.

Outstanding Examples

The Consolidated Mining and Smelting Co. of Canada, with headquarters at Trail, British Columbia, has perhaps made as extensive use of airplanes in connection with its recent exploration work as any mining concern on the American Continent.

In the spring of 1929 the company brought some of its examining mining engineers to Trail and provided them with flight instruction until they received their commercial air-pilot licenses. When the ice broke on the lakes and rivers in the northern mining areas, two of these engineers started out in De Havilland Gipsy Moth airplanes, equipped with pontoons. These ships are light, two-place, open-cockpit, folding-wing biplanes with four-cylinder, inline, vertical air-cooled, direct-drive, 95-hp. Gipsy engines. Each examining engineer-pilot was accompanied by an airplane mechanic who also assisted with mine sampling and similar work.

The following year, 1930, the company trained several more engineers during the winter months. In the spring, two additional Gipsy Moth airplanes were purchased and sent out with engineer-pilots and airplane mechanics.

As aerial exploration developed successfully, three larger air-craft were operated for about $2\frac{1}{2}$ years. These heavier machines consisted of one Fokker Super-Universal cabin monoplane and two Fairchild (71) cabin monoplanes, each powered with a Wasp 420-hp., Pratt and Whitney, radial air-cooled, direct-drive engine. The larger planes served as freighters to carry food, gasoline, and supplies to caches near where the smaller planes were operating. They also were used to carry men and supplies, including drilling and camp equipment, into remote regions. In this way, properties under option were speedily investigated and drilled. Then smaller planes were also purchased for the transportation of the company's officials.

To March, 1931, this company's airplanes had flown approximately 425,000 miles since the first machine was put into operation. There was not a single failure of an engine in flight or a single injury of a serious nature to personnel. A considerable portion of the mileage is credited to the engineer-pilots who received their training in company-owned airplanes. Most of the flying was done under the wide variety of conditions encountered in the remote mining districts of northern Canada. In the summer time the airplanes were equipped with pontoons. In the winter time the pontoons were replaced by skiis.

During 1931 "Consolidated" aircraft flew a total of 3,028.8 hours, covered 273,726 miles, and carried 1,817 passengers and 247,897 pounds of freight.

Costs of operating the two-passenger Gipsy Moth airplanes in the Canadian Northwest have been announced as approximately 35 cents per plane-mile. This figure includes all expenses such as engine and aircraft overhauls, insurance, depreciation, gasoline, oil, and all operating and adminstrative costs other than engineer-pilots' salaries. Overhauls and mechanical work of all kinds were done at the company's shops at Trail.

From the foregoing record it appears that mining and petroleum companies operating in the United States could reduce costs and increase supervisory efficiency considerably by giving pilot training to some of their district managers, superintendents, geologists, engineers, and highly paid service men who now spend a considerable part of their time driving automobiles. The furnishing of light, stable, slow-landing airplanes to some of these men who are building up automobile mileage at a surprising rate is recommended for consideration. From available information it appears that the operating costs of many of their automobiles are slightly higher than would be the cost of operating suitable airplanes.

A letter from John C. Rogers, consulting mining geologist, of Toronto, states that his organization has had excellent results in the operation of airplanes by mining engineers and geologists with pilot-training. He considers it advisable to have a pilot who understands thoroughly what is sought by the field men and that in isolated districts the second man should be a first-class mechanic as well as an observer or mapper. Pilots should not be permitted to fly alone.

Prior to March 1929 the Northern Aerial Minerals Exploration, Ltd., commonly designated as N.A.M.E., had flown more than 100,000 miles over northern Canada without a single casualty, according to details published by its staff in the Canadian Mining and Metallurgical Bulletin for March 1929, summarized as follows:

"Much of the flying was over virgin territory probably never before visited by white men. Some of it was over regions that abound with possibilities for minerals. All of it was done for exploration and the establishment of bases and supply stations for carrying men and their tools and provisions to remote locations."

Some advantages gained by the use of the airplane in the North are pointed out by J. E. Hammell, president of the organization, in the Transactions of the Canadian Institute of Mining and Metallurgy for 1929, as follows:

"1. Safety: From 1928 until March 1929 there were no casualties among air passengers, where about 42 men lost their lives through the hazards of more primitive types of transportation.

"2. Communication and supervision. These provide the key to effective prospecting. Parties are at all times in touch with district engineers at headquarters and receive help and advice on the ground when they need it. Effectiveness is tremendously increased.

"3. Morale. This is increased out of all proportion to other factors. Men are in touch with civilization and have had the worry and labor of transportation of supplies removed. They can apply themselves fully to the work of prospecting within a convenient radius of their main camp. When they have finished with a particular locality they, their canoes, and their supplies are transported to another area and work resumed in a fraction of a day.

"4. Aerial observation. Geological boundaries can be outlined roughly by an engineer or an experienced prospector. Topographic features of the country can be supplied to the field parties in remarkably quick time."

Transportation is probably the biggest problem the prospector has to face. According to the staff of the N.A.M.E., the airplane eliminates this for him. The prospector can be carried in a few hours to regions that ordinarily could not be reached in weeks of travel. He can be kept supplied with food, explosives, and tools.

Transportation is at present by far the most important role of the airplane. Under it may be included:

(a) Placing parties completely equipped in previously selected localities.

(b) Keeping these parties supplied with food, dynamite, drill steel, and tools. Because of transportation difficulties prospectors rarely have carried the latter aids into the wilderness.

(c) Carrying in additional men, equipment, and supplies without loss of time if results of preliminary work warrant more intensive prospecting.

(d) Moving parties without loss of time from one locality to another when the work in an area is completed.

(e) Placing parties early in the season (April) in selected localities, giving them a 6 or 8 weeks's start before the best prospecting months of the year, May and June. The difficulties in connection with placing parties before break-up by ordinary transportation methods are so great that it is rarely attempted except in localities close to railways.

By such methods one scouting party in a single season can line up areas for intensive prospecting during the following season that could easily keep a small army of prospectors busy.

Methods of operation, organization, personnel, division of personnel, lists of equipment, and details of work performed in specific areas are included in the original article cited, with a general discussion of cost factors and remarks on increase in safety due to the use of airplanes.

With the organization of flying companies in northern Canada, some of the mining exploration companies, including N.A.M.E., have found it more economical recently to buy aerial transportation than to maintain their own flying equipment and staff. When an area has been partly developed so that the addition of larger crews is justified and the amount of freight for continuous movement has increased a mining company perhaps may be justified even under present conditions in considering the air transportation of its own freight.

Views of Experienced Pilots

The prominence of Major T. G. Lanphier, president of the Bird Aircraft Corporation, in the field of aviation makes his views of special interest. The following has been summarized from his letter of October 27, 1931:

> "That suitable planes can be operated safely by men of limited experience is shown by the fact that a large number of plane owners are private people who have no interest in commercial aviation and who do not fly frequently. It is possible for a normal person to learn to fly a Bird plane in 4 hours of instruction and immediately thereafter be his own observer if he is a geologist.
>
> "A pilot with any degree of skill can land and take off safely at high altitudes with suitable planes, particularly if they are equipped with superchargers. Handling a plane in stormy weather on the ground

is simple. It is only necessary to stake down the airplane and keep it in a sheltered spot. Even if the spot is not particularly sheltered from high winds, a plane staked down properly should give no trouble.

"Cruising near the ground to examine its geological features is particularly simple with our planes. The practice is referred to as hedge hopping and it is necessary for the plane to maintain a low forward speed if the geological observations are to be accurate. It is possible to cruise along with the plane at much less than 60 miles an hour, which, from reasonable altitude, makes preliminary geological observations practical."

Newton Wakefield, vice president and general manager, Mamer Air Transport, gives some of his views in a paper on "Mine Development by Airplane" in the Engineering and Mining Journal for May 1932, page 264, as follows:

"The usefulness of the airplane in the mining industry has not been adequately appreciated or exploited. During recent years the airplane has been utilized extensively to aid mining engineers and geologists in scientifically prospecting for new orebodies and new oil deposits. This use has been rather more extensive in Canada and Alaska than in the United States.

"Usually, the plan is to fly a geologist over the region to be prospected and to let him study the general relation of outcrops and other geological features visible from the air. Aerial pictures may be taken and any interesting country mapped by building up a mosaic of aerial photographs. The geologist finally reduces the entire area under consideration to small sections which appear to have the most promise."

Central landing fields are then located, and prospectors, equipment, and supplies are flown to these points. The prospectors are assigned definite areas to cover, and every 2 or 3 weeks they return to the landing fields with samples they have taken. Samples are examined and assayed with a portable outfit set up at the landing field or are flown to the nearest assay office. The engineers and field geologists are thus able to keep complete records of the work being done. They can concentrate the prospectors in areas which give the most promise as shown by samples and examination of the work done. In this way all work is under the control and supervision of the field engineers or geologists; plans are carried out in a scientific and systematic manner; and large areas can be prospected thoroughly in the shortest time possible.

Aerial maps are complete in every detail and give the engineer a pictorial representation impossible to obtain in any other way. They contain such a wealth of detail that it is often possible to lay out roads, power lines, tramways, and other surface developments on the aerial maps without making further surveys. Aerial pictures, aerial maps, and aerial reconnaissance can help the mining engineer in hundreds of ways. In the future, the aerial camera will be as much a part of his equipment as the transit is today.

Wakefield's article describes the modern transport plane, its capabilities, and its limitations and shows how it may be employed by the mining industry in solving problems of preliminary exploration and transportation. It is stated that a transport plane of one of the earlier Ford Trimotor types can carry a 3,000-pound cargo at 100 miles an hour and that with this load it will land on and take off from small fields.

Usually, suitable landing fields can be built at small expense by felling trees and grading runways or by smoothing out the rough spots in a meadow. In the Idaho-Montana area the United States Forest Service estimates the cost of preparing this type of field as about the same as that of building a mile of trail. No subsequent maintenance is necessary in many areas.

The direct cost of air transportation of equipment into remote areas frequently is far below that of any other method. The saving in time usually means a heavy reduction in ultimate costs.

Some Unit Costs in Alaska

Frank Dorbandt, commercial airplane operator at Anchorage, Alaska, contributed a letter containing some interesting unit costs of airplane operations in his district. His observations are summarized as follows:

> "Air-transportation costs vary with the size of the organization. I am operating alone and have only one mechanic. I am using a six-passenger Pilgrim monoplane with a pay load of 1,257 pounds on skis and 896 pounds on pontoons. These pay loads are set by the Aeronautics Branch of the United States Department of Commerce.
>
> "In summer, of course, our operating costs are higher because of the lower pay loads. My operating costs average $60 an hour, including depreciation, insurance, mechanic's salary and expenses, my own salary as a pilot, and the various other items which make up the cost of operation. Gasoline averages 50 cents a gallon and oil $1.25 a gallon.
>
> "I average about 600 hours a year at a cruising speed of approximately 100 miles an hour. My plane is insured for $11,000 against fire only, at a cost of 5 percent. I carry $10,000 to $50,000 passenger liability and $20,000 public liability insurance. Our insurance premiums amount to $1,085 per year. We write our ships off in 3 years, the depreciation being 40 percent the first year and 30 percent each the second and third years.
>
> "Our average charge per passenger-mile is about 35 cents, and our average freight charge for 200-mile distances is 30 cents per pound, corresponding to about $3.00 per ton-mile."

Arctic and Winter Flying

W. J. McDonough, in an article published in Aviation Engineering for March 1933, stated that the chief value of the airplane as an aid to mineral exploration could be divided into eight distinct functions:

"1. The rapid and safe transportation of prospectors, food supplies, and equipment from one northern point to another, thus more than doubling the efficiency of the prospector by saving time.

"2. The extension of the prospecting season by many weeks because of the ability to reach quickly remote districts in a few hours.

"3. Opportunity to visit prospecting parties by regular patrol and supply their requirements as well as keep them in touch with headquarters and to fly them out in case of business demands or illness.

"4. Coordination of a company's exploration effort by flying supervisory engineers and geologists to any district from which important information has been received through various bases.

"5. The rapid inspection of claims regarding which information has been received and the confirmation or rejection of reports which otherwise might cause unwarranted effort.

"6. Flights by large freight aircraft carrying complete mining staff for the investigation of distant areas, with supplies and equipment sufficient for extensive examination of properties.

"7. Flights carrying directorial heads on tours of inspection to ascertain water-power resources and timber supply of any district in relation to mining development.

"8. Cooperation with Government departments in the rapid organized development of northern Canada as regards its mineral resources."

High-wing monoplanes are preferable, due to conditions of operation encountered in the field. It was stated that nearly all airplanes used on transportation service in Canada have been equipped with Pratt and Whitney Wasp 9-cylinder, radial air-cooled engines. Strong preference was expressed for single-engined planes because of the delay due to warming engines with plumbers' pots to get them started in the morning. A cruising speed of 100 miles per hour for 6 hours without refueling is considered desirable, but it is extremely important that landing speed under full load should not exceed 53 miles per hour. The airplanes most suitable for use should be able to take off from glassy water with a pay-load of 2,300 pounds and 5 hours' fuel supply in 40 seconds. Desirable minimum pay-load capacity of cabins was given as 250 cubic feet, although planes in use were said to have only 150 to 170 cubic feet of pay-load space.

In conclusion, it was stated that take-off ability and low-landing speed should be given the primary consideration for this type of service. The application of slots and flaps seems to be a solution to this problem. A landing speed of 60 to 65 miles an hour is much too high for safe operation and makes conditions extremely dangerous when a landing becomes necessary on rough water or on hard-packed or drifted snow.

H. A. Oaks on Air-Transport in Canada

H. A. Oaks, Airways, Ltd., Toronto, in a letter to the author makes the following statements in reference to planes for transport:

(a) Transport aircraft to have sufficient capacity to be effective must have at least 400 hp. An air-cooled engine of proved type is preferable. Reconnaissance aircraft should have air-cooled engines of 150 to 200 hp.

(b) Disposable load (total licensed load less weight of aircraft empty) should be about 2,700 pounds for transport and 1,200 pounds for reconnaissance.

(c) All-metal construction is preferable. Even if a hangar is available at headquarters, the airplanes will be in the open most of the time.

(d) Cruising speed with floats should not be less than 95 miles an hour. It is advisable to have transport and reconnaissance machines with approximately the same cruising speed so that they will be able to travel together conveniently.

(e) Rugged construction for possible winter operation in the Far North, with consequent rough going.

(f) The aircraft should be seaworthy to give maximum service for extended summer operations, some of which may be on big inland waters. Delays due to weak float undercarriage are expensive. Unnecessary risks of capsizing or foundering cannot be tolerated.

(g) Quick take-off and good climbing ability are highly essential for operation into and out of small lakes and rivers. The equipment should have a service ceiling of at least 15,000 feet to insure satisfactory operation in the mountains.

(h) Adaptability for aerial photography is required.

Personnel. -- To save weight and expense men of dual capacity should be chosen. Pilot-mechanics are obtainable. They can be trained to assist in mine sampling. Pilot-geologists and pilot-engineers are rare but are extremely desirable for such work. Experience has shown that an engineer or geologist who has not flown considerably as a pilot is a distinct financial hazard. Too frequently, he loses his effectiveness as a geologist and engineer if his flight training and experience are inadequate.

"Authority to use aircraft. -- To eliminate joy-riding and unnecessary flying, all flying is classified as "reconnaissance," "transport," "test," or similar service, and each flying job must be requisitioned by someone in authority."

After the cost of flying is estimated, a rate should be set up, making a fixed charge per mile or per hour or per pound, depending upon the nature of the work. All flying should be charged at this rate against the operation for which it was performed. It is advisable to make the rates high enough to give the flying branch a small paper profit on its operations.

A complete field record of flying operations should be kept.

Aerial Oil Reconnaissance

Following are fragmentary notes from correspondence and conversation with Stuart Moir, western sales manager for Fairchild Aerial Surveys, Inc.:

"Some emphasis should be placed on the fundamental difference in the requirements for surveys made for petroleum reconnaissance as against those made to locate mineral deposits. Generally, the following has held true for experience and practice in the United States:

1. Petroleum surveys have covered large areas and required relatively small-scale maps.

2. Mineral surveys usually have covered relatively small areas and required large-scale maps.

The big area in Africa mapped by the Aircraft Operating Co. of London covered over 60,000 square miles, according to available information. These surveys were for a three-fold purpose: (1) Land classification, (2) locating mineral-bearing areas, and (3) mapping a new country prior to colonization.

From the Dallas, Texas, headquarters aerial maps were prepared of more than 30,000 square miles for oil reconnaissance. The area included many of the major producing fields, such as Yates Pool, Winkler, Luling-Mexia fault line and the Balcones fault line in Texas, and the entire East Texas Basin. Hobbs field in New Mexico was completely mapped as were many of the domes in the Gulf region of Louisiana and Texas.

In Mexico extensive surveys have been made in the States of Tamaulipas, Nuevo Leon, Vera Cruz, Tabasco, and Yucatan.

Considerable visual reconnaissance by airplane has been done by mining engineers and geologists in Sonora, Chihuahua, Sinaloa, Zacatecas, Durango, and Guerrero, and there are probably other aerial surveys of which nothing is generally known. The Military Engineer for March and April, 1933, has details of the Guatemala-Honduras boundary survey, made through cooperation of the United States Geological Survey and the United States Army Air Corps.

The cost of operating a four-passenger cabin Fairchild airplane (FC2) in Mexico over a period of approximately 4 years was 22.75 cents a mile.

This included depreciation, taxes, and all operating expenses. All charges for the operation of an FC2W Wasp-powered Fairchild in Mexico came to 28 cents a mile.

The operation of a seven-passenger Fairchild 71 with a Wasp engine amounted to 30 cents a mile over 700 to 750 hours of flying.

Exclusive of the pilots' salaries, the charge for operation of a 300-hp. photographic plane is about $30 an hour, based upon about 400 hours of flying per year.

Flying for photographic work sells for $50 to $60 an hour, including the pilot and taking into account the relatively small number of hours flown in a year. This figure includes $2.71 an hour for insurance of the type carried for photographic work ($100,000 to $200,000 public liability, plus coverage for plane damage by tornado or fire, plus theft protection).

The cost of aerial maps and surveys depends upon so many factors that an offhand estimate is likely to have little value. Such factors as the scale of the maps and the probable use to which they will be put are important. The elevation of the area to be mapped is of particular importance. Distance from headquarters of the mapping concern and whether there are other jobs to be done in the immediate future in the area where the mapping is undertaken, have a decided bearing on costs. The safest way to arrive at the cost of the work is to prepare specifications covering the scale and the accuracy required, and other details, and to call for estimates for concerns accustomed to making aerial maps.

In making oil surveys, we are accustomed to think in terms of square miles, whereas in making mineral surveys usually we think in terms of acres.

Aerial-map interpretation is an art. A high degree of efficiency in reading this type of map can be acquired only after considerable study and field experience.

There is every indication that with the rapid progress in aerial development, costs of aerial maps will be reduced and their accuracy increased in the near future.

Among the advantages of using aerial-survey methods for pipe-line location may be mentioned the following:

1. A right-of-way man can show a land owner exactly where the proposed line will cross his ground, without the owner being antagonized by surveyors running lines on his property; also, a survey can be made without the land owner realizing it.

2. The shortest and most convenient and hence the most economical location can be made within a minimum time.

3. Changes in operating plans which may require changes in location occasion a minimum of lost time for resurvey. Due to the large amount of detail on aerial-survey maps, changes can be considered and decisions reached immediately in many cases.

4. The pipe-line contractor can submit a more intelligent bid owing to the large amount of detail shown on the aerial-survey map.

5. Transportation and stringing costs are reduced because trails, roads, highways, and topography near the right of way are shown in great detail.

6. Obstacles are shown in such detail that it is easy to avoid them.

7. Stream-crossing expense is minimized by selection of the more favorable crossings. The wealth of detail on the photographs makes it possible to estimate stream-crossing costs more accurately.

Aerial Surveys in Relation to Economic Geology

Bulletin 337 of the Institute of Mining and Metallurgy, October, 1932, contained an interesting paper by Donald Gill on "Aerial Survey in Relation to Economic Geology." The following points of practical interest to the geologist are given special mention:

1. It is desirable that all the photographs in a mosaic should have been taken at approximately the same time of day to avoid confusion in shadow effects.

2. It is highly desiragle that all joins should be straight edges, rather than that they should be camouflaged by following some undulating feature, for example, a road, the edge of a forest, or a stream, as is sometimes done. It should be impossible to mistake a join for anything else in mosaics used for scientific purposes.

3. It is preferable that there should be a frank break in detail at a join rather than that the mapping should be fudged in any way - for example, by stretching the emulsion of the prints when wet.

The proper use of aerial surveys and photographic maps expedites and increases the accuracy and detail of geological and other work in connection with the development of mineral deposits. The savings effected in the development and other work usually will exceed considerably the cost of the aerial work. Furthermore, the right kind of aerial surveying will minimize the chances of overlooking nearby deposits which may prove to be of economic value.

Aerial surveys expedite and reduce the cost of construction of railroads, highways, trails, aerial tramways, power transmission and telephone lines, pipe lines, and similar auxiliary developments.

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3. It is preferable that there should be a frank break in detail at a join rather than that the mapping should be fudged in any way - for example, by stretching the emulsion of the prints when wet.

The proper use of aerial surveys and photographic maps expedites and increases the accuracy and detail of geological and other work in connection with the development of mineral deposits. The savings effected in the development and other work usually will exceed considerably the cost of the aerial work. Furthermore, the right kind of aerial surveying will minimize the chances of overlooking nearby deposits which may prove to be of economic value.

Aerial surveys expedite and reduce the cost of construction of railroads, highways, trails, aerial tramways, power transmission and telephone lines, pipe lines, and similar auxiliary developments.

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AIR TRANSPORTATION OF FREIGHT

Recent developments indicate that where the cost of ground transportation of freight exceeds 11.5 cents per ton-mile consideration should be given to the use of aerial transportation.

Where the air transportation of all freight is not justified the employment of auxiliary airplanes is suggested for consideration to reduce expensive delays in the shipment of bullion, high-grade concentrates, perishables, emergency repair parts, emergency supplies, samples, drill cores, and similar items.

In the following summaries the reader should bear in mind that many of the instances cited were pioneering efforts. The experience gained may indicate the advisability of variations in methods and equipment on future transportation jobs. Development of both equipment and methods has been extremely rapid. Hence, yesterday's best practice in air transportation may be poor when measured by the standards of tomorrow.

Without defending or criticizing the types of equipment chosen, the author has given such available cost data and details as could be procured for some actual uses of aircraft to transport mining and petroleum equipment and supplies into isolated districts.

Freight Transportation in New Guinea

One of the outstanding accomplishments is described by C. A. Banks, managing director, Bulolo Gold Dredging, Ltd., in an article published in Bulletin 334, July, 1932, of the Institution of Mining and Metallurgy, London. This is supplemented by additional data from the Junkers Corporation of America in July, 1933.

The Bulolo placer deposits are situated in New Guinea approximately 7° south of the equator and 35 miles in a direct line from the coast. The surface elevation averages 2,250 feet above sea level. As there are no roads through the dense tropical jungle, drilling and shaft testing were conducted with supplies and equipment sent from the coast to the interior by airplanes capable of transporting about 2,000 pounds per trip.

When sampling results had proved satisfactory it was decided to equip the property with two 10-cubic foot, all-steel dredges (now working) and a 3,000-hp. hydroelectric plant, and possible methods of transporting such equipment were given full consideration.

The country between the coast and the dredging ground is rough. A mountain range, the lowest pass through which is about 4,000 feet above sea level, has to be crossed. A road would have to be 90 miles in length. Construction would require 12 to 18 months. It would cost more than a million dollars. Even with a road completed, the cost of hauling would be heavy. Road upkeep would be extremely expensive because of the heavy rainfalls.

Air transportation of men and supplies for preliminary testing and prospecting operations had been entirely satisfactory. After full consideration of the many factors involved, including sectionalizing of equipment to reduce the size and weight of individual pieces, it was decided to abandon all idea of a road and to transport all machinery and equipment from the coast by airplanes. The total weight of the two dredges and the hydroelectric plant was estimated at 2,400 short tons. It would be necessary to transport 200 tons monthly not to delay construction.

Transportation equipment. - Two Junkers G-31 trimotored, low-wing passenger monoplanes, altered and strengthened to suit requirements, were purchased. With any two of the engines in operation the maintenance of a reasonable elevation is possible with these planes.

Spare parts. - During the transportation of 2,500 short tons, requiring about 1,000 trips, engine trouble developed in one flight only, when the center engine failed. The loaded plane finished the flight without difficulty with the remaining two engines.

Landing fields. - Construction of a suitable landing field at Bulolo was a major undertaking. A sandy gravel site was chosen on the downstream end of the property just off the dredging area. Dense, tropical jungle with trees exceeding 4 feet in diameter had to be cleared and a large drain placed along the upper edge to keep the field free of surface water. To reduce bumpy landings due to air currents produced by reflected heat of the sun, the entire area was planted with couch grass.

The Bulolo air field took 7 months to complete and cost approximately $30,000. Cutting the grass has been the only maintenance required since completion. With planes weighing approximately 19,000 pounds striking the ground at 75 miles an hour a soft surface cannot be tolerated. With good surfacing the wear and tear from landings and take-offs has been small.

Airplane operations. - Airplane operations were conducted by an airways company under a contract which included management and other facilities.

The flying distance from the coast airport to Bulolo and return is approximately 100 miles. The flying time for the round trip averages 75 minutes. The average altitude attained in crossing the mountains is 6,000 feet. Loads carried have averaged about 5,400 pounds. With improvements in the Lae landing field, however, they will be increased to about 6,000 pounds or more.

The airplanes are designed to carry long pieces as well as heavy pieces, hence they cannot be flown empty. For the return flight ballast must be placed in the aft compartment of the otherwise empty plane to make the tail weight approximately 2,000 pounds. Water ballast could be used, but gravel was needed at Lae, hence gravel in bags was used for ballast.

Loading and unloading operations. - A 10-ton, locomotive-type crane loads the planes at Lae. Its position is just behind the wing. Cargo is always loaded and unloaded from the rear so that in case of accident the load would fall on that part of the fuselage which is most easily repaired.

The concrete loading apron is fitted with platform scales for weighing the tail of the plane to make sure that its weight always is between 1,800 and 2,000 pounds when the loading operation is completed. Cargo is shifted to keep the weight between these limits.

After a little experience, loading time was reduced to 20 minutes or less. Only ten minutes were required to load dredge buckets.

A careful inventory of each load was made to facilitate replacement with minimum delay in case of accident.

A hand-operated, stiff-leg crane is used for unloading at Bulolo. Unloading requires about half the time needed for loading.

The anticipated difficulty in securing cargo in the cabin did not materialize. Heavy pieces of machinery were lashed in position by light, steel cables attached to the floor and sides of the cabin. The cables were fastened around the machinery with clamps and drawn tight with turnbuckles. No trouble has been experienced due to cargo shifting.

The upper tumbler shaft, which was 12 feet long and weighed nearly 7,000 pounds, was carried in four cradles set on the main transverse beams of the cabin floor. With concentrated loads, rubber pads were introduced between the load and the wooden cradle to absorb shock in landing and taxiing. Some less heavy, but awkward, parts were carried on bags of rice needed for food.

Progress. - Two additional dredges and two more hydroelectric units are in course of transportation. One of these additional dredges was scheduled for operation in September, 1933 and the next in May, 1934. In addition, general supplies, spare parts, and other necessities are being transported continuously for the operation, bringing the weight of material transported by airplane well above 5,000 tons.

Costs. - Total field costs for air transportation of 2,500 tons, including all handling of cargo from ship side to airplanes, were $182,000, or $72.80 per short ton, equivalent to $1.45 per ton-mile (using $3.50 to the Australian pound).

The records to July, 1933, show that the airplane service for the Bulolo Gold Dredging, Ltd., includes 12,500,000 pounds of freight, 11,000 passengers over a period of 5 years, and a total distance traveled of 1,000,000 miles. The staff included 7 pilots, 20 mechanics, and 28 helpers. This service has been carried on without the loss of any freight and without a serious accident.

Freight Transportation By Alaskan Airways

Following is a brief of a statement by H. [illegible] Katz of the Alaskan Airways, Inc:

Air transportation is already an important factor in Alaska. Considering the sparcely settled nature of the country, doubtless it will become increasingly important in the future.

Instances where aircraft are used in the development of mining operations in the Territory are of almost daily occurrence. Radio communication is fairly well established throughout the interior and requests are received regularly at the bases of the Alaskan Airways for replacements of broken machinery, for spare parts, and supplies.

An outstanding instance of the use of the airplane in this connection occurred in the spring of 1932: Sixty or more bucket lips, weighing approximately 100 pounds each, were taken by airplanes from Anchorage to the dredge of the New York-Alaska Gold Dredging Co., 500 miles or more in the interior, in the vicinity of Akiak. The only other way to have transported these lips would have been by steamer from Seattle to Bethel at the mouth of the Kuskokwim River, where they would have been transhipped to a small river boat and carried some distance farther. They would then have to be hauled by tractors a long distance over trails, and delivery could not have been made until too late for the lips to have been of any use that season, as the first steamer to Bethel left Seattle on May 21. Accordingly, the bucket lips were sent by ship to Seward and over the Alaskan Railroad from Seward to Anchorage. From there the Alaskan Airways carried them into the interior and were able to leave them within a short distance of the dredge. All of the bucket lips were delivered in plenty of time for the dredge to commence digging as soon as the weather permitted. Had there been no airplane service, the loss to this operator would have been serious, amounting to practically an entire season's work.

Another instance was when a shipment of dynamite and fuse, destined for Medfra on the Kuskokwim River, missed the last steamer from Seattle. This material would have gone from Seattle to Bethel and transhipped there to a river boat for Medfra. With the close of water transportation there would have been nothing to do but wait for favorable conditions and haul the material in with dog teams. However, as airplane service was available this shipment reached its destination in ample time for Anchorage, and there was no loss of time at the mine. Use of dog teams to serve this section of the country appears to be almost a thing of the past now that aerial transportation is available.

Gold bullion is regularly handled by airplane from many interior points to Anchorage and Fairbanks for shipment to the outside. This means much to the operators because there is no loss of time in getting the gold out.

Freight Transportation in Canada

Airplanes continue to play an important part in the development of new mining districts in Canada. Although air transportation of heavy freight has not been undertaken to the extent that it is employed in New Guinea, the use of airplanes capable of carrying from 1,200 to 2,000 pounds of freight has been perhaps more extensive in the mining districts of Canada than in any other area of the world.

These airplanes have been employed mostly in the earlier stages of prospecting and development to transport men, diamond-drilling outfits, food, and other supplies into the newer districts. As a rule, the planes have been equipped with floats during the summer months and with skis for winter operations. Much of the flying has been done by chartered equipment belonging to air-transport companies, although many routes in mining districts have been flown on regular schedules by air-transport operators carrying passengers, mail, and express.

During the season of 1932, Canadian Airways, Ltd., added to its equipment a single-engine Junkers Ju-52 plane capable according to the manufacturer, of carrying a pay-load of 4,950 pounds for a distance of slightly more than 600 miles without refueling when equipped as a land plane. Float equipment doubtless would reduce the pay-load or the cruising radius, or both. Such equipment should make possible the transportation of heavier loads at lower rates, and its purchase indicates anticipation of additional demand for the transportation of heavy freight into mining districts.

Great Bear Lake District. - With regard to aerial transportation in the Great Bear Lake area, the Canadian Mining Journal for July, 1932, contained these items:

> From March to September, 1931, Spence-McDonough's three airplanes covered a distance of 53,500 air-miles in the mining districts of northern Canada. They carried 40,000 pounds of pay freight between Waterways, northern Alberta, and Great Bear Lake. Included in this work was the transport of a complete diamond-drilling outfit to the most northerly point at which such work had been done on the continent. None of their ships so much as damaged a brace during the season, although much of the flying was done under extremely unfavorable conditions.
>
> From Waterways to Great Bear Lake is approximately 800 miles. The 20 tons of freight mentioned was transported by air at a maximum of 80 cents per pound, or $2 per ton-mile, including complete insurance coverage on the freight.
>
> Water transportation from Waterways to Great Bear Lake is open for only 2½ months during the year. The boat rate has been approximately $320 per ton, or 40 cents per ton-mile, but 4 to 6 weeks are required for water transportation, as compared with only 12 hours by air.

Ontario. - C. F. Jackson, mining engineer with the United States Bureau of Mines, contributed the following note regarding air transportation for the Ashley gold mine, Matachewan district, Ontario:

> Although most of the heavy material and equipment for the Ashley gold mine was hauled in by winter road, 45 tons were transported by airplane during 1932. This freight was flown from Elk Lake (a widening of the Montreal River) to Ashley Lake (formerly called Whitefish Lake), three miles from the mine. The distance between landings is approximately 32 miles. A 4-place, 320-hp. Bellanca with a cruising speed of approximately 100 miles an hour and a pay-load with floats of about 1,150 pounds was used for the freight transportation. The trip required 20 to 25 minutes.
>
> The plane was operated by General Airways, Ltd., with a passenger fare of $10 one way (31¼ cents per passenger-mile) and a freight charge of 6 cents per pound, ($3.75 per short ton-mile). Surface transportation cost for 1,412 tons hauled over winter roads was 64.6 cents per short ton-mile, or about 17 per cent of the air-transportation cost.

Freight Transportation in Mexico

G. C. Quick, pilot for El Paso Air Service, contributed the following, under date of June 16, 1932:

> I am operating for the El Paso Air Service a Bellanca Pacemaker equipped with a Wright J-6 motor, over an 80-mile run from Mazatlan to Contra Estaca, Sinaloa, Mexico. I find that it is not advisable to land on my field at the Mexican Candelaria Mining Company at Contra Estaca after 10 a.m., as it is a mountainous country and my approach is poor; the field being an improvised one, 1,750 feet long and 200 feet wide, made by a bend of the Elota River, and situated between steep canyon walls.
>
> My operating cost per flying hour averaged $27.50 U. S. Currency on this particular run, making an average of 40 trips monthly. The flying time each way averaged 38 minutes, making the average flying time per trip 76 minutes.
>
> Miscellaneous freight including drill steel and structural steel pieces weighing as much as 1,500 pounds, also fresh vegetables, groceries, and supplies, are flown to the mine, and I carry gold and silver bullion back to Mazatlan; also such other miscellaneous cargo as it may be necessary to ship. Passengers are also carried. I hauled approximately 100 tons from January 1 to June 16, 1932. Operations have been perfect.
>
> The only other existing means of transportation to this particular mine is by pack train, which takes 5 days each way as compared with 38 minutes flying time as stated above. I know no other make of plane that would be better suited for this particular run.

The flying cost on this run is given as 29.03 cents per ton-mile. Apparently, this figure does not include depreciation, insurance, or pilot's salary, although full details could not be procured.

Durango. - During the 7 months prior to November 1, 1932, the San Luis Mining Co. of Tayoltita, Durango, transported 198.4 short tons of freight by airplane. This included supplies to the mine and bullion from the mine to the outside. The air-route is approximately 84 miles long, making 168 miles flown on a round trip.

Freight Transportation in the United States

Airplanes have been used for the transportation of freight into mining and petroleum districts of the United States to a much less extent than in Canada and Alaska. In certain isolated districts where ground transportation facilities are poor and the weather in general is favorable, the possibilities appear to be excellent for further development of economical air transportation of heavy freight for mining and petroleum operations.

Aircraft have been used by petroleum and mining companies of the United States for transportation of executives and salesmen, for emergency transportation of repair parts and supplies, and for advertising. However, as yet they have not been employed to any great extent for the transportation of heavier freight.

It should be pointed out that most air-transportation developments in the United States have been directed to a steady increase in speed, with important sacrifices being made to attain this objective. A brief study of air-transportation problems makes one reluctant to challenge the wisdom of these sacrifices for commercial air-line operations. It should be indicated, however, that in the air transportation of freight for mining or petroleum operations, the cruising speed of the aircraft is of minor importance when compared to such factors as weight-carrying capacity, stability, dependability, slow-landing characteristics and, in some instances, ability to land and take-off from small, rough landing fields, and to climb rapidly to avoid obstructions in the take-off.

A contribution from Newton Wakefield, mining engineer, vice-president and general manager, Mamer Air Transport, on available flying equipment is summarized as follows:

> There are many types of airplanes on the market, ranging from the fast single-seater to the large single and multimotored transport planes. There are land planes, seaplanes, and amphibians, all of which have their special uses. There are comparatively few, however, that are suited for transportation of heavy machinery for mining and petroleum operations. The choice of equipment depends in each instance on the work to be done which imposes certain limitations upon the types of planes to be used. The restricted area of landing fields eliminates the use of planes with fast landing speed. The competition of surface transportation usually makes it impractical to use high-speed equipment where pay-load is sacrificed for speed. The comparatively high altitude of some landing fields imposes further restrictions.

Rather than to go into a technical discussion, it may be stated in general that planes used in mining and petroleum transportation work should have the following characteristics, which will be varied somewhat with the weight of single loads to be transported and the local conditions of operation:

Comparatively slow landing-speed, high rate of climb, large pay-load, economy in operation, comparatively long cruising range, sturdy construction and ease of loading and unloading are important factors to be considered. In general, all-metal construction has received the preference over metal and fabric construction, particularly where heavy loads are to be carried and where hangars are not available. While fairly high cruising speed is desirable under certain conditions, it is by no means essential, and other factors are far more important.

Idaho. - It appears that more mining supplies and freight have been transported by air in the Idaho-Montana Districts than elsewhere in the country.

The Idaho Sunday Statesman for May 8, 1932, contained an article entitled "Winged Freighters" by Bert Eustis, from which the following information is summarized:

> During the winter of 1931-32, airplanes regularly supplied food and news of the outside world to a number of isolated and snow-bound mountain villages in Idaho.
>
> The service was maintained by ski-equipped planes operated by pioneer pilots without the benefit of beacons and lighted, clearly marked, well-tended airports. There were no beam radios to assist the pilots in keeping on their routes which lay over rough mountain peaks. The doubtful landing fields are thousands of feet above sea level where the take-offs are difficult and sometimes almost impossible. Snow clouds hang low almost all winter and the air is rough and full of pockets. Only a few minor mishaps occurred, such as damaging propellers or skis on landing. Passengers and mail have been taken in and out of the villages. Express and food have been flown in to relieve distress. Necessary freight has been hauled to the mines to permit them to continue operation and supply employment. Injured miners have been rushed from isolated districts to the more efficient hospitals of the larger cities.

United States Forest Service: The freight transportation problems of some mining and petroleum operations in isolated districts are not dissimilar to those of the United States Forest Service. Hence, the following summary, prepared from information furnished by the northern district of the United States Forest Service may be of interest:

During the 1931 season, 129,413 pounds of freight was delivered by airplane an average air-line distance of 60 miles from Missoula, Montana, at a contract price of 5.5 cents per pounds, corresponding to a ton-mile cost of $1.833. The materials ranged from eggs to ready-cut buildings. All freight was delivered in excellent condition without mishap, to emergency landing fields in inaccessible mountain areas over passes with an elevation of 7,000 feet or more.

During the 1930 season, 116,000 pounds of similar freight was transported by pack horse at a cost of 7.3 cents per pound, corresponding to $2.43 per ton-mile or 32.7 percent more than the cost of air transportation.

AIR TRANSPORTATION OF PERSONS IN THE UNITED STATES

The increased use of light aircraft for transportation of officials and supervisory and service employees in the mining and petroleum industries is a highly promising field. During the past two years the development of suitable types of craft for this purpose has been considerably more rapid than may be generally realized. The author is convinced that in many instances the effectiveness of more highly paid employees could be doubled by using suitable aircraft at only a slight increase in the present cost of their transportation. In some instances the present cost should be decreased. Before discussing this phase in detail, however, it is desired to present summaries of individual air transportation costs actually developed for some allied phases of the problem.

Conventional types of larger airplanes with fair cruising speeds have proved reasonably satisfactory for the transportation of company directors and highly paid executives. The indirect cost of such flying has been high, due principally to the small number of hours flown and to the use of large, multi-motored planes. In some instances, flying costs have been increased to prohibitive amounts, (1) by using large, expensive planes only 10 to 15 hours per month, (2) by the continuous employment of pilots, co-pilots, and traveling mechanics for little-used equipment, and (3) by the construction of private flying fields and hangars which are used to only a slight extent.

Flying Costs: The factors that determine the actual cost of air transportation of persons are perhaps more numerous than those which control the cost of automobile transportation. The questions of weight, design and size of equipment, horsepower of engines, first cost and hence depreciation of equipment, hours of use per year, whether stand-by pilots and mechanics are continuously employed, elevation and character of terrain over which operated, weather conditions of area in which operated, the cost of landing-field and hangar facilities, local costs of gasoline, oil, mechanical repairs and check-ups, as well as the character of the equipment and the kind of service in which operated, all naturally have a vital bearing on the cost of flying.

A major petroleum company reported that it operated a Hornet-powered, Boeing 40B mail plane at a cost of $45 per flying hour or 39 cents per plane-mile, including pilots' and mechanics' salaries and expenses, hangar expense, fuel and lubrication cost, repairs and renewals, taxes, insurance, and depreciation. As this particular ship carries 3 passengers in addition to the pilot, the cost is equivalent to 13 cents per passenger-mile, exclusive of pilot. Insurance is rather expensive as it includes public liability and property damage, in addition to life insurance policies of $25,000 each on the pilot and three passengers. During a period of 43 months prior to June 1, 1932, the plane had been flown a total of 1,886.4 hours, over a distance of 182,075 miles, and 4190 passengers had been carried.

In Western Flying for January 1933, page 22, the cost of flying a Stinson Junior plane some 65,000 miles during 1932 is given as 15.94 cents per plane-mile, including continuously employed pilot's wages, depreciation, insurance, fuel, maintenance, and contingent items. The plane was used in north-central Nebraska in connection with ranch operations.

W. A. Mara, vice president of the Stinson Aircraft Corporation, stated that during 1931, the average operating cost of all the company's district salesmen's 4-place cabin Stinson Jr.-S planes throughout the United States was 8.46 cents per mile. The figures ranged from 6 to 11 cents per plane-mile, depending upon the locality and the amount and character of operation of the individual planes. These figures include servicing and repairs, storage and the purchase of gasoline and other necessary items at any airport where the salesmen happened to have their planes for demonstration.

The Martin-Decker Corporation, an oil-well supply firm with headquarters at Long Beach, California, has furnished estimates of the cost of flying its 4-place Stinson cabin monoplane, with the exception of insurance and miscellaneous storage costs. The Stinson Junior was purchased in May, 1929, for $5,775. To October 30, 1932, it had been flown 870 hours at approximately 100 miles per hour at a cost of 7,958 cents per plane mile.

C. F. Williams, district mining supervisor for the United States Geological Survey, headquartered at Miami, Oklahoma, provided a good example of the results attendant upon the use of aircraft in connection with his work. He has used three small cabin monoplanes, fitted with engines ranging from 90 to 110 hp. At present, he is using a Star-Cavalier 90, a 2-place cabin monoplane with a 90 hp. Lambert engine. Between July 1 and December 31, 1931, the plane was flown 18,400 miles, at an operating cost of 3.59 cents per plane mile exclusive of storage, resulting in a time saving of about 30 percent under that required for automobile travel in the same district.

Gasoline and oil consumption.- Some approximate estimates of gasoline and oil consumption at cruising speeds for radial air-cooled engines in common use, as established by practical experience are as follows:

Gasoline and oil consumption of certain engines

Rated hp.	Gasoline, gal. per hour	Oil, gal. per hour
400-420	18 - 25.0	0.66
300	16 - 21.3	.61
240	13 - 14.5	.46
215-220	11.5 - 13.0	0.39 - 0.41
160	8.0 - 10.5	---
125	6.3 - 8.9	.11 - .26
110	7.4 - 8.2	.19 - .45
100	6.0 - 7.0	---
90	5.7 - 7.0	---

Because of the number of variables introduced under actual flight conditions, consumption easily may exceed the higher figures given for each power rating. Fuel consumption in pounds per horse-power-hour is published by the engine manufacturers.

The cost of flying decreases rapidly as the number of hours flown per year increases. For the employee who could make effective use of 400 to 600 hours of air transportation per year the cost per mile should be considerably under that of automobile transportation, and the time saving and increase in effectiveness would be proportionately greater.

It is the opinion of the author that oil companies, in particular, could gradually reduce their costs of field supervision to a considerably extent by establishing their own flight instruction departments and training selected individuals as private pilots. As their courses of instruction are completed, these men could be equipped with suitable light aircraft to be used for individual transportation in connection with their duties in the oil fields, where conditions are favorable. As the hazards and costs of automobile driving are increased considerably when one car is driven by several individuals, so the hazards and costs of flying would be much increased by passing an air-plane from one individual to another for use in the oil fields. Thus, the author is forced to the conclusion that the wiser plan would be to utilize low cost equipment and provide selected individuals with small planes for their sole use.

The adoption of such a plan naturally would incur the building up of mechanical and servicing units within the organization quite similar to the automobile repair and servicing units now functioning.

Although the light airplane has some weather restrictions, probably being held on the ground during bad weather when a car could get through, on the other hand, on fair days following bad weather such as snow or heavy rains and floods that have blocked the roads, the airplane could go through in safety, when automobiles could not get through.

LANDING FIELDS

Many mining operations are conducted in mountainous localities. Not infrequently, however, it is possible without undue expense to get two runways of about 2,000 to 3,000 feet in length and 300 to 400 feet in width at approximately 90 degrees. Sometimes the general direction has to be changed somewhat to suit the prevailing air current. The two runways need not be connected and can be a mile or two apart if necessary, if they are both kept in fairly close proximity to the loading point. If, as frequently happens, the operation is in rough country, the construction of a landing field may present a serious problem.

If the mining or petroleum operations are on or near a body of water, seaplanes and float-equipped land planes can be used successfully for transport work. In general, however, the pay-loads of planes so equipped are less than those of landplanes of similar gross weight. Suitable locations, of course, are not numerous in mountainous districts. The number of available places for the construction of landing fields at comparatively low cost in many areas, however, is rather surprising. Places that justify careful examination can be found most easily as a rule by flying over the area. Flat benches, sandbars, and meadows frequently make good fields. Graded waste and tailings dumps have been used to advantage.

The United States Forest Service has constructed some landing fields in inaccessible localities in the national forests of the Northwest. They include some good fields in the Selway, Idaho, and Flathead National Forests. They are available, of course, for mining companies in the districts as concentration points to receive supplies and materials for development work in the vicinity.

The Forest Service has prepared specifications for air transport landing fields to provide for the transportation of forest fire-fighters. These specifications might be of service to mining or petroleum companies contemplating the air transportation of freight.

It has been stated that on occasion the Forest Service has found that the cost of clearing and preparing a landing field suitable for transport airplanes in forest areas has been comparable to the cost of building a mile of trail through those areas. In a special instruction circular issued by the Forest Service, the following vital features are recommended for consideration in selecting fields for transport planes.

1. Since changes in direction of flight are to be avoided in the first half mile from the field, locations should be chosen so as to exclude major obstacles so far as possible within a half-mile radius of the outside of the field.

2. Obstacles in the direction of the prevailing wind are especially bad.

3. The cleared ground should be nearly level. Slopes of 2½ percent are not objectionable. Slopes up to 5 percent are acceptable but not desirable.

4. The runway must be reasonably firm and so surfaced that a car can be driven over it at 25 miles an hour. A firm, smooth surface is highly important for a heavy plane.

5. The approaches to the field must be up to the specifications shown in the attached sketch (sketch omitted).

6. A runway at right angles to the main runway is desirable, it may be in a second field as near to the first as the conformation of the ground permits. The availability of this secondary runway at right angles to the first is of increasing importance where the direction of the wind varies over wide limits. Conversely, where the prevailing direction of the wind is fairly constant, the importance of the secondary runway decreases.

DEPENDABILITY OF AIRPLANES

Weather conditions are of paramount importance in considering the maintenance of flying schedules in comparison with the maintenance of schedules for ground transportation. There is considerable variation in percentage of schedules actually flown as against those planned for different sections of the United States. Some idea as to allowances to be made for delays due to climatic conditions can be obtained by studying Aeronautics Branch figures for miles scheduled and miles actually flown for various sections of the United States. Such figures are published from time to time by the Aeronautics Branch of the Department of Commerce in its AIR COMMERCE BULLETIN.

Although means of ground transportation may be continued during weather unsafe for flying operations, it should be noted that immediately upon the break-up of a storm, flying may be resumed if landing fields are in usable condition. Roads and trails, on the other hand, may be blocked by snow, landslides, fallen timber, and other results of storms so that a much longer time would be required to resume ground transportation. Thus, where climatic conditions are unfavorable, actual delays in truck, tractor, pack-train, or dog-team transportation may be considerably greater than the delays entailed in grounding flying equipment during the height of the storms.

A brief review of miles flown per accident for scheduled air transports as well as for miscellaneous flying operations in the United States, according to the Air Commerce Bulletin, will give a rough idea of the dependence which the mine or petroleum operator may place in his specially operated air-transport facilities.

Figures released by the Assistant Secretary of Commerce for Aeronautics in Air Commerce Bulletin, May 1, 1933, show that in scheduled air transport operations 5,862,103 passenger-miles were flown per passenger fatality during 1932. In miscellaneous flying operations the miles flown per passenger fatality were 587,810 during 1932, as against 623,514 for 1931. The miscellaneous flying operations designation included student instruction, experimental flying, miscellaneous commercial flying, sight-seeing, dusting crops, aerial photography, and pleasure flying.

On the basis of figures announced by the Aeronautics Branch, it appears that the average air-line passenger could travel around the earth 1,000 times on scheduled air-lines before he would run a chance of becoming involved in a fatal accident, or he could travel on an air-line for 481 years before he would be involved in a fatal accident.

GENERAL SUMMARY

1. Airplanes can be made to reduce the time and cost of prospecting and exploration work, particularly in remote areas. They can increase the safety and effectiveness of men employed on exploration, prospecting and mineral development operations. The employment of mining and petroleum engineers and geologists who have been thoroughly trained as pilots is recommended.

2. The choice of suitable flying equipment for mining and petroleum operations is important. High cruising speed is relatively unimportant for most airplanes used in these industries. Such characteristics as dependability, stability, comparatively low landing speed, quick take-off, high rate of climb, large pay-load, economy of maintenance and operation, comparatively long cruising radius, sturdy construction, and similar characteristics which would be varied to fit conditions are far more important than high speed.

3. Aerial surveys can be made to expedite geological and engineering work in connection with the development of mineral and oil deposits. When properly made they increase the accuracy and reduce the cost of geological and engineering as well as development work. To be effective they should be made by men thoroughly trained and experienced in aerial methods, particularly in the accurate interpretation of aerial photographs.

4. Suitable aircraft capable of cruising safely at low speeds would be especially valuable for geological and engineering reconnaissance and similar work including quick and accurate location and routine inspection of pipelines, long aerial tramways, power transmission and telephone lines, location of trails, roads, highways, railroads, camps, available water power, water supply, timber for mining and construction purposes, and similar auxiliary projects.

5. When the estimated cost of ground transportation of freight exceeds 11 cents per ton-mile, when the ground transportation cost of individuals exceeds 5 cents per mile, or when available ground methods are slow or otherwise unsatisfactory, consideration should be given to the use of aerial transportation.

6. Even when ground transportation is fairly cheap and satisfactory, auxiliary air transportation should be considered for executives, sick or injured persons, bullion, high-grade concentrates, perishables, emergency repair parts, emergency supplies, samples, drill cores, and similar items. Airplane ambulance service is of particular importance in remote areas.

7. In many instances the cost of mining and oil operations could be reduced and effectiveness could be increased to a considerable extent by increasing the use of suitable airplanes, under favorable conditions.

8. The training of selected employees as private pilots and the substitution of suitable airplanes for various forms of ground transportation under favorable conditions would reduce supervisory, operating, transportation, and other costs while increasing effectiveness in the industries under consideration. In many instances the total cost of operating suitable light pilot-yourself aircraft should be less than the present cost of operating automobiles.